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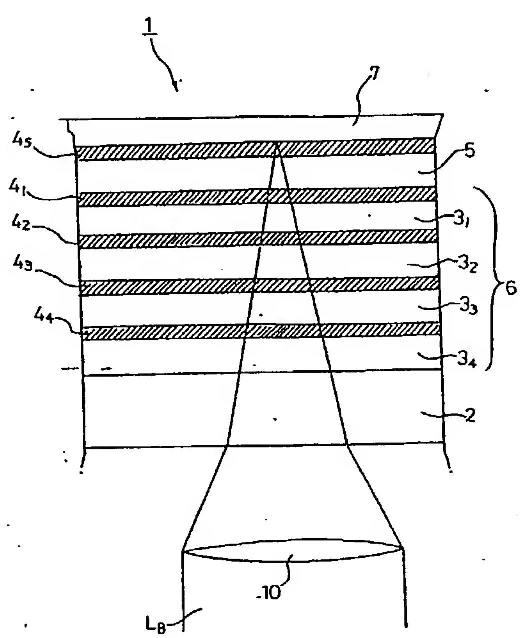
(54) Optical recording medium and recording/reproducing method therefor.

(57) An optical recording medium and a recording method therefor in which a recording layer group and a light-absorbing and heat-generating layer for absorbing radiated light to convert the absorbed light into heat are formed on a substrate. The recording layer group is formed of thermo-sensitive recording layers capable of recording thereon information in the form of a light signal stacked alternatingly with heat insulating layers. Laser light emitted from a luminous source in a recording apparatus is condensed through an objective lens so as to be focused on the light-absorbing and heat-generating layer, so that when heat of a predetermined quantity or more is generated by the light-absorbing and heat-generating layer, the heat reaches the recording layers successively stepwise due to the heat insulating functions of the respective heat insulating layers.

FIG. 1



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BACKGROUND OF THE INVENTION

The present invention generally relates to an optical recording/reproducing method for recording/reproducing an image, audio information, or the like in accordance with optical information, and particularly relates to an optical recording medium and a recording/reproducing method making it possible to perform high density recording/reproducing.

Conventionally, optical disks such as an audio compact disk (CD), a video disk (VD), and the like, on which recording/-reproducing of optical information can be performed have been very widely used.

Although there are certain problems with conventional disk, however. For example, a required disk-drive control system is complicated and expensive, optical disks are widely because they are superior to conventional recording media in many regards. For example, an optical disk recording can be made with much greater density, one or two orders of magnitude, than a magnetic recording because the signal is recorded/reproduced using a small light spot having a size of about the wavelength of light. Also, an optical disk has a signal surface which is not worn during use so that it is superior in non-volatility of recording (holding of recorded data) because the reproduction of the recorded information is performed by a noncontact method using a light beam.

In conventional optical disks, the signal is recorded as a series of binary values indicated by whether a hole (pit) exists or not in a light reflection surface of the disk, and information is expressed by a pit length (size) and a pit interval. There are two recording types, one being an analog recording such as laser vision or the like in which the pit length and pit interval vary continuously, the other being digital recording such as a digital compact disk or the like in which the pit length and pit interval discretely vary. In analog recording, generally, although any signal can be recorded so as to obtain an extremely high information packing density, there is a problem concerning the accuracy of the recorded signal and the accuracy of signal reproduction whereby noise in optical and electric systems directly affects the signal-to-noise ratio of the reproduced signal.

In digital recording, on the other hand, the recorded information can be accurately reproduced if the mark length can be discriminated. Further, digital recording has the advantage that even if a certain amount of error exists, the original correct information can be restored using an error correcting code. In digital recording, however, since the mark size must be discretely distributed within a predetermined range of length as described above, the number of marks is unavoidably limited, and it is therefore a matter of course that the recording density is limited.

As described above, in the case of a binary signal formed by a series of pits, a recording method in which the pit size, pit interval, and track interval are made small to thereby improve the recording density has been used conventionally. In making high the recording density, and correspondingly the processing speed, however, there has been a limit to the achievable recording density, even if the size of a recording signal is made as small as absolutely possible, due to the binary nature of the signal and in that a large number of bits (a large number of combinations of pits) is required in order to express complicated information.

In view of this situation, a method using a multi-valued recording signal (multi-recording) has been proposed in order to further improve the recording density. With respect to this method, a photochemical hole burning method (PHB) is considered to be promising. This method is, however, very difficult to be put to practical use at present because it is necessary to very precisely control the temperature of the recording apparatus.

Also, for example as disclosed in Japanese Patent Unexamined Publication No. Hei-1-319134, there has been proposed a method in which the mark diameter is changed by changing the quantity of light (the quantity of energy) of the recording laser light to thereby record a multi-valued signal on the basis of the light reflection factor corresponding to the value of the mark diameter.

In this method, however, the changes in the recording signal are difficult to distinguish from the case where the signal changes in a continuous manner. The method is therefore not significantly different from the previously described conventional techniques. More specifically, multi-valuing is carried out using a plurality of threshold values of the quantity of recording light as determined by changes in the recording spot diameter. However, the output power level of the recording signal beam generating laser generally unavoidably fluctuates in a range of about 1 to 2 mW, so that an error is caused in the recorded mark diameter. Since as the number of available multi-level values is increased the intervals of the threshold values become less, at a certain number of multi-value levels the fluctuations in the recording beam power level make it impossible to accurately distinguish between adjacent recorded levels.

SUMMARY OF THE INVENTION

An object of the present invention is to solve the foregoing problems in the prior art and to provide an optical recording medium and a

recording/reproducing method in which a signal, which can be multi-valued, can be very accurately written and read out.

The foregoing and other objects of the present invention can be attained by an optical recording medium characterized in that a recording layer group and a light-absorbing and heat-generating layer for absorbing radiated light to convert the absorbed light into heat are formed on a substrate, the recording layer group being formed of thermo-sensitive recording layers capable of recording therein information in the form of a light signal and heat insulating layers, the thermo-sensitive recording layers and the heat insulating layers being alternately stacked one-on-one in three or more layers, and the light-absorbing and heat-generating layer being formed in a position so as to contact the recording layer group.

The foregoing object of the present invention can also be attained by a method using the foregoing recording medium, that is, by a method of recording/reproducing optical information in which a light-absorbing and heat-generating layer for absorbing specified light to convert the absorbed light into heat is irradiated with laser light focused on the light-absorbing and heat-generating layer, and in which, by use of a recording layer group disposed adjacent to the light-absorbing and heat-generating layer and formed of thermo-sensitive recording layers and heat insulating layers alternately stacked one on one in layers, a multi-valued signal pattern is recorded based on stepwise concentration changes of the thermo-sensitive recording layers due to modulation of the laser light.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a partial sectional view showing a preferred embodiment of an optical recording medium according to the present invention; and

Fig. 2 is a graph showing the relation between the number of recording layers and changes of concentration of a signal.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described hereunder with reference to the accompanying drawings. The present invention, however, is limited only to these embodiments.

Fig. 1 is a partial sectional view showing an optical disk, which is an optical recording medium according to the present invention. In an optical disk 1, thermal-sensitive recording layers 3_n and heat insulating layers 4_n are alternately stacked one-on-one in plural layers so as to form a signal recording layer group 6 on a transparent substrate 2.

In this embodiment, the recording layer group 6 is constituted by four recording layers 3_n (3_1, 3_2, 3_3, and 3_4) and four heat insulating layers 4_n (4_1, 4_2, 4_3, and 4_4). A light-absorbing and heat-generating layer 5 for absorbing radiated light to convert the absorbed light into heat is formed on the recording layer group 6, and a flat reflection layer 7 made, for example, of aluminum, gold, silver, or the like is formed on the light-absorbing heat-generating layer 5 through the heat insulating layer 4_5. The reflection layer 7 is formed by an evaporation method, a sputtering method, or the like.

Each thermal-sensitive recording layer 3_n may be formed, for example, of a phase-change material such as InSe or an imidazoquinoxaline-type coloring material so that the layer is colored by application of heat. In the recording layer group 6, each heat insulating layer 4_n is disposed between two thermal-sensitive recording layers 2 and has the function of suitably controlling heat transmission between the thermal-sensitive recording layers 3_n. Each heat insulating layer 4_n may be formed, for example, of a high molecular material such as silicon oxide (SiO_2), Teflon, or the like. Further, each heat insulating layer 4_n is transparent.

The light-absorbing heat-generating layer 5 may be formed, for example, of a cyaninedie or the like so as to effectively generate heat by light illuminated onto the layer.

Description will be made as to a signal recording method using the recording medium having a configuration as described above.

Laser light L_B emitted from a luminous source of a recording apparatus is condensed through an objective lens 10 so as to be focused on the light-absorbing and heat-generating layer 5. As a result, the light-absorbing and heat-generating layer 5 absorbs the light and generates heat. Then, when the quantity of the generated heat reaches a predetermined value or more, the heat reaches the first recording layer 3_1, overcoming the heat insulating ability of the first heat insulating layer 4_1. As a result, although the first recording layer 3_1 is colored, the second recording layer 3_2 adjacent thereto is not colored because of the heat insulating function of the second heat insulating layer 3_2. Since the heat insulating ability of each of the heat insulating layers permits a change of the quantity of heat generation due to fluctuations of the output of the laser light L_B, the writing accuracy of the recorded signal is made extremely high due to the lack of any effect caused by fluctuations of the laser power. That is, it is possible to prevent generation of defective recording caused by fluctuations in the laser light output because the width of the laser power (LP) from the first critical point to the second critical point is very large in comparison with the magnitude of the fluctuations in the output of the writing laser beam, as indicated in

Fig. 2. A signal corresponding to a first concentration level C_1 in Fig. 2 can be written by maintaining the laser power P_n in the range of $P_1 \leq P_n < P_2$, as described above.

In order to establish the second concentration level C_2, it suffices to make the quantity of light intensive by modulating the laser light L_B or to prolong the time of radiation of the laser light L_B to thereby make the heat reach the second recording layer 3_2. In this manner, by adjusting the quantity of light as described above (the same applies to the other points P_2, P_3, and P_4), the third and fourth recording layers 3_3 and 3_4 can be successively colored. Thus, it is possible to perform writing in the state where the concentration levels are clearly separated into five stages from C_0 to C_4.

Thus, laser light is directed onto the light-absorbing and heat-generating layer 5 to cause the layer 5 to absorb the laser light L_B and convert the absorbed light into heat, and the thermo-sensitive recording layers 3_n and the heat insulating layers 4_n are alternately stacked one-by-one in plural layers adjacent to the light-absorbing and heat-generating layer 5, as described above. Accordingly, when the heat generated in the light-absorbing and heat-generating layer 5 is transmitted in the direction of the thickness of the recording layer group 6, the heat insulating functions of the respective heat insulating layers 4_n can clearly discriminate changes of heat between the recording layers, that is, the respective heat insulating layers act as threshold values, which do not cause misidentification of signals. Consequently, recording and reproducing can be performed to obtain a very clear signal on the basis of a multi-valued signal pattern by discrete changes in concentration in the recording layer group 6 utilizing changes in the number of recording layers. This is accomplished without changing the size of the recording mark.

In the reproducing operation, on the other hand, the reflection layer 7 is irradiated with the reading laser light, and a read-out signal is produced on the basis of the quantity of the reflected light. In this case, as easily seen also from Fig. 2, the signal can be reproduced as the stepwise discrete signals (C_0, C_1, C_2, C_3, and C_4). Therefore, slight fluctuations of the laser light output during the recording operation will not affect the quality of the recorded signal. Accordingly, not only is the discrimination of the signal good so as to make the recording reliability high, but it is also possible to accurately reproduce the stored information even if the accuracy of a reproducing apparatus is not particularly high.

According to the present invention, the coloring of the recording layers 3_n is not limited to colors within the visible spectrum, but it is a matter of course that wavelengths other than those within the visible spectrum be used. That is, the coloring is not specifically limited. This is because, for example, a layer change in a recording layer which easily absorbs laser light in the reproducing operation can be regarded as coloring. Thus, it is possible to produce an effective difference in concentration by changing the substance of the recording layer so that it can easily absorb wavelengths equal to or approximate to that of the laser light used for reproducing.

The heat insulating layer 4 may also function to prevent heat generated in the light-absorbing and heat-generating layer 5 from escaping to the side of the reflection layer 7.

Although the light-absorbing and heat-generating layer 5 is disposed in opposition to the substrate 2 with the recording layer group 6 therebetween in this embodiment, the present invention is not limited to this arrangement, and, for example, the configuration may be such that the light-absorbing and heat-generating layer 5 is disposed so as to be closer to the substrate than the recording layers 3_n, or disposed inside of the recording layer group 6.

Although a five-valued signal is used in this embodiment, it is a matter of course that more than five levels can be used. A three-valued signal can be obtained in the case of providing two recording layers; generally, when an N-valued signal is required, it suffices to provide (N-1) recording layers.

The recording medium according to the present invention is not limited to that for exclusive use for reproducing, but it is a matter of course that the recording medium can be a write-once type.

Further, although the recording medium in this embodiment has a configuration in which the reflection layer 7 is provided, the present invention is not limited to this arrangement. That is, the reflection layer 7 may be eliminated if desired. For example, the recording medium may have a configuration in which the recording layer group 6 is sandwiched between light-permissible supports (substrates), and a recording signal is detected by detecting the quantity of light of the light transmitted through the recording layer group 6, so that it is possible to exceedingly accurately obtain a reproduced signal.

According to the present invention, there is provided an optical recording medium in which a recording layer group and a light-absorbing and heat-generating layer for absorbing radiated light to convert the absorbed light into heat are formed on a substrate. The recording layer group is formed of thermo-sensitive recording layers capable of recording thereon information in the form of a light signal and heat insulating layers. The thermo-sensitive recording layers and the heat insulating lay-

ers being alternately stacked in plural layers, the light-absorbing and heat-generating layer being formed in a position so as to contact the recording layer group. Accordingly, for example, laser light emitted from a luminous source in a recording apparatus is condensed through an objective lens so as to be focused on the light-absorbing and heat-generating layer, so that when heat of a predetermined quantity or more is generated by the light-absorbing and heat-generating layer, the heat reaches the recording layers successively stepwise due to the heat insulating functions of the respective heat insulating layers. As a result, a multi-valued signal can be digitally expressed. When heat generated by absorption of laser light is transmitted in the direction of the thickness of the recording layer group as described above, the heat insulating functions of the respective heat insulating layers make it possible to clearly discriminate changes of the transmitted heat in every recording layer. Therefore, without changing the size of the recording mark as in the conventional optical recording medium, a very clear signal can be recorded in the form of a signal pattern on the basis of a stepwise change of concentration in the recording layer group utilizing a change of the number of recorded layers, that is, a change in the mark depth direction, and the thus-recorded signal can be reads as a signal having a stepwise clear concentration difference.

As described above, in the recording medium and recording/reproducing method according to the present invention, an exceedingly large number of signal patterns can be recorded/reproduced as stepwise discrete signals, and therefore not only is the reliability of the signal improved, but also slight changes in the laser light output during the recording operation can readily be easily tolerated. Further, it is possible to accurately reproduce the recorded information even if the accuracy of the reproducing apparatus is not great.

Claims

1. An optical recording medium comprising: a substrate, a recording layer group, and a light-absorbing and heat-generating layer for absorbing radiated light to convert the absorbed light into heat formed on said substrate, said recording layer group comprising a plurality of thermo-sensitive recording layers capable of recording thereon information in the form of a light signal arranged alternatingly with a plurality of heat insulating layers, said light-absorbing and heat-generating layer being formed in a position so as to contact said recording layer group.

2. The optical recording medium of claim 1, further comprising a light-reflecting layer formed adjacent said light-absorbing and heat-generating layer.

3. The optical recording medium of claim 1, wherein said thermo-sensitive recording layers are formed of a phase-change material.

4. The optical recording medium of claim 3, wherein said phase-change material is InSe.

5. The optical recording medium of claim 3, wherein said phase-change material is a imidazoquinoxaline-type coloring material.

6. The optical recording medium of claim 1, wherein said heat insulating layers are formed of a high molecular material.

7. The optical recording medium of claim 6, wherein said high molecular material is SiO_2.

8. The optical recording medium of claim 6, wherein said high molecular material is Teflon.

9. The optical recording medium of claim 1, wherein said heat insulating layers are transparent to a wavelength of light used to record said medium.

10. The optical recording medium of claim 1, wherein said light-absorbing heat-generating layer is formed of a cyanine-die.

11. A method for recording/reproducing optical information, comprising the steps of: providing an optical recording medium comprising a light-absorbing and heat-generating layer for absorbing light to convert the absorbed light into heat disposed adjacent a recording layer group layer formed of a plurality of alternatingly stacked thermo-sensitive recording layers and heat insulating layers, radiating said light-absorbing and heat-generating layer with laser light focused on said light-absorbing and heat-generating layer, and modulating the power of said laser light to record a multi-valued signal pattern as stepwise concentration changes of said thermo-sensitive recording layers due to modulation of said laser light.

FIG. 1

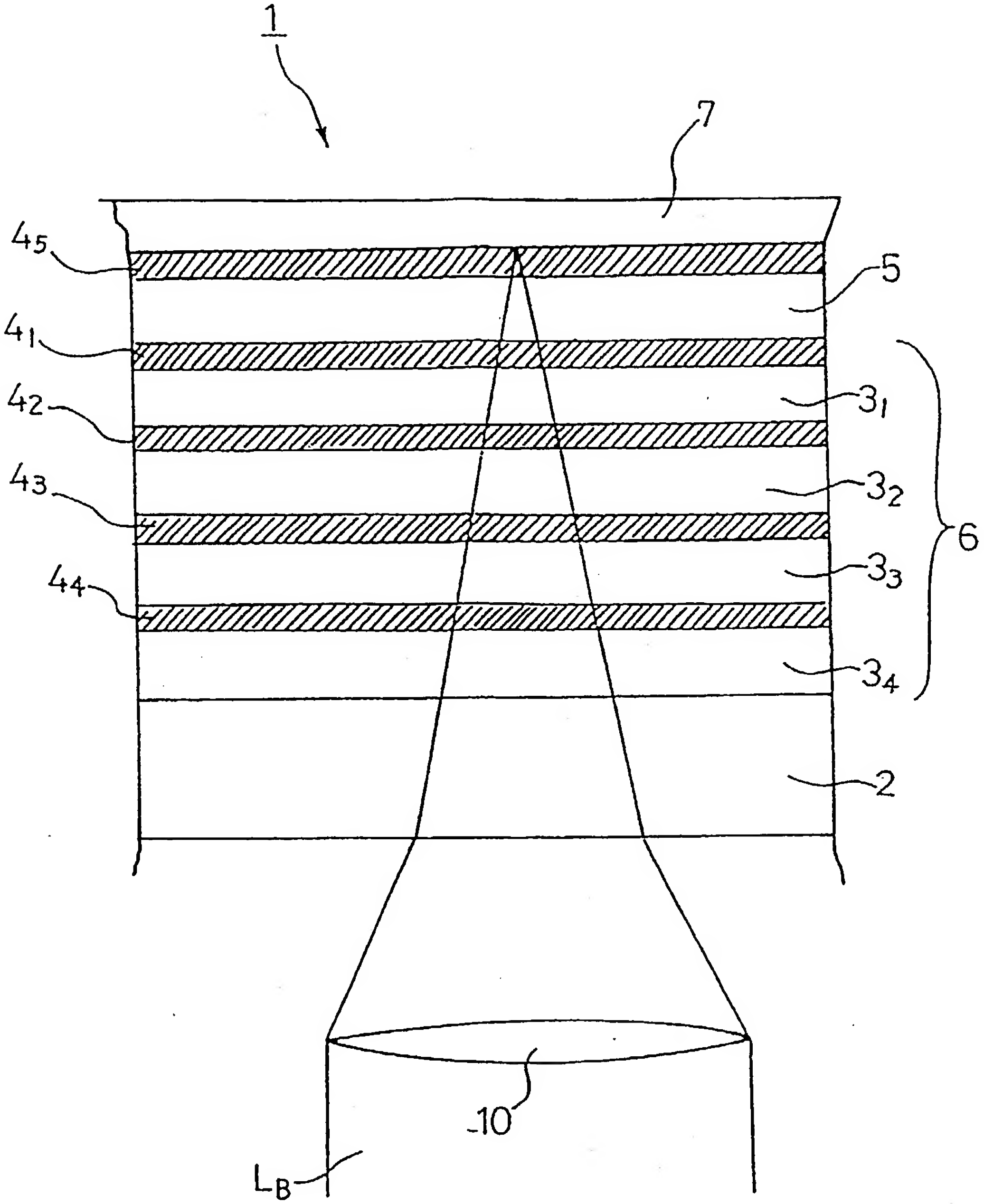

FIG.2